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Traffic network and the urban environment: an adapted space syntax approach

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Abstract

The general idea of Space Syntax approach postulates that, the total network of public spaces which is defined by the natural form of the urban tissue in every settlement or city, can be considered as a single and continuous spatial system. This system can be divided into components, analyzed as networks of choices, and then represented as maps and graphs that describe the relative connectivity of those spaces. Among the Space Syntax analysis methods the most widely used is the integration analysis which identifies the preferred shortest route between two points in a given street network. Although paradoxes arise using this method, many research results from European and American cities of different morphology have claimed strong connectivity of preferred routes and traffic volume generated by city planning choices (land use, population density, etc). The proposed adaptation of the chosen Space Syntax methodology is applied to Xanthi, a Greek medium size city in Northern Greece with a very interesting variety in the form and density of its urban tissue. It is the purpose of this application (which uses the DepthMap program) to verify and interpret the functional structure of the city through identifying the form of its core, the principal and most congested road axes, the allocation of the central land use etc. Moreover, it aims to verify the argument that the space syntax attributes of the urban public space have an impact on the accomplishment of the objectives in the regeneration studies and are able to affect the development and structure of its central functions.

Keywords: Space syntax; urban tissue; urban configuration

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1. Introduction

Space Syntax, a well-known methodology of urban analysis, is based on the use of computer techniques to analyze urban configuration. Its origin lies on the work of Hillier and Hanson (1984); since that year it has been developed at the Space Syntax Laboratory of University College London as well as at its various affiliates worldwide. Some important references in the field are the books by Hillier and Hanson (1984), Hillier (1996), and Hanson (1998), as well as the proceedings from a series of biennial symposia, since 1997 (Ratti, 2004).

This paper focuses on the application of the Space Syntax method of integration to Xanthi, a city of approximately 55,000 inhabitants, situated in the north-eastern part of Greece, which has a particularly interesting variety in the form and density of its urban tissue. This variety includes the existence of traditional parts with organic tissue, newer extensions with rectangular grid or organized building activity, and different religion and cultural groups.

The method was applied twice, one before and one after a recent urban planning intervention which unified the open urban spaces in the city centre. This intervention involved the pedestrianization of parts of principal road axes, as well as point traffic arrangements, but without the implementation of an integrated transport study, creating new conditions in the function of the whole city.

With the first application of the method, it was attempted to verify and interpret the functional structure of the city until nowadays by examining the form of its core, the main and more congested road axes, the allocation of the major land use, the non – incorporated (segregated) areas etc. The second application verified the argument that the syntax attributes of the urban public space have an impact on the completion of the regeneration projects' objectives and can influence the development and structure of its central functions.

2. Space Syntax methodology

Space Syntax's procedure is based on the representation and quantification of environmental characteristics of the built environment with the aim to use them as independent variables for a statistical analysis of observed behavioral patterns such as routes and flows (Penn, 2003).

According to Space Syntax theory, the total urban spaces network, defined by the natural form of the urban tissue of every settlement or city, can be considered as a single and continuous spatial system (Hillier and Hanson, 1984). This system can be divided into components, followed by the analysis as networks of choices and the representation using maps and graphs which illustrate the relative connectivity and integration of those spaces.

The most widely used Space Syntax analysis method is integration. Integration method uses shortest path algorithms in order to measure the number of turns one would have to make when located at a street segment to reach other street segments in the network. In case where the amount of turns required for reaching all segments in the graph is analyzed, the analysis is said to measure integration at radius n (global integration). It is not necessary to apply the integration analysis to the whole network; it can also be applied and analyzed in local scale. If the integration is measured at radius 3 for instance, only three turns are counted departing from each street segment. The Space Syntax integration value represents the degree of integration of the initial segment in the system. A higher value indicates more connectivity to the network while a lower one shows segregation (Hillier et al, 1993). The results of the analysis are

presented in colored axial maps, in which each axis has a differentiation in color depending on its integration value, ranging from red (high values) to purple (low values).

A schematic approach of space syntax analysis relies on the concept of graphs. An informal definition of the graph suitable for this analysis could be the following: a graph is a finite set of dots called vertices (or nodes) connected by links called edges (or arcs). In the case of the axial map, the streets play the role of the vertices of the graph while their interconnections correspond to the edges. The integration measures are well – established topological parameters (Hillier, 1999).

Evidence from a large number of research studies under the supervision of Hillier, with case studies located in more than 100 European and American cities with different urban tissue morphology has proved that:

The integration parameter influences a lot the degree of urban space use (liveliness, underdevelopment, isolation), as it is strongly correlated with the daily chosen paths and trip density from one point of an area or city to another (natural movement) (Hillier, 1996, Vaughan, 2007). In the majority of cases, there is a directly equivalent correlation between integration and density of use. This leads to the conclusion that the greater the integration value of a road, the higher is the density of the commuters in this particular road (Penn et al., 1998).

The integration core, which corresponds to the 5% - 10% of the most integrated spaces and is the syntax centre of an area, tends to attract those functions that seek centricity. In contrast to that, the enclosed cells of the tissue, which consist of syntax isolated streets, usually are residential location for extreme socio – economic groups: low, when combined with degraded built environment and dynamics or high when combined with high quality of built environment (Gospondini, 2005).

The integration analysis can apply to all scales of public space, ranging from a square to a metropolitan area level; the results between different cities are directly comparable. Moreover, the method's analysis tools are independent from the measurable attributes of the built environment. This was a major point of criticism of the method (Ratty, 2004, Hillier and Penn, 2004). Recent research studies have proved that the concept of distance is topological on settlement level or part of a city and metric on a particularly local level (Hillier et al, 2007).

Space syntax can compare to transport models, though it was pointed out that they are based on different representation systems: transport models are characterized by node-link representation, whereas Space Syntax is based on a graphic representation of the environment highlighting the morphologic structure of an urban area (axial map) as a starting point to describe spatial configuration (Nenci and Troffa, 2007).

3. The city of Xanthi: Historic evaluation and urban configuration

The city of Xanthi is located in an altitude of 60 – 145 m. An interesting parameter concerning the process of urban configuration of the city is its relation with the geophysical landscape: the large gradients have defined the form and development of the historic core and the flat lowland zones have defined its modern extensions (Figure 1a).

Xanthi exists as an organized fortified settlement from the byzantine years and was developed significantly during the middle of the 16th century. In the beginning of the 19th century, the city had a population of 3,000 inhabitants and began to extend beyond its initial residential core. The city was totally destroyed in 1829 by two disastrous earthquakes but it was not abandoned.

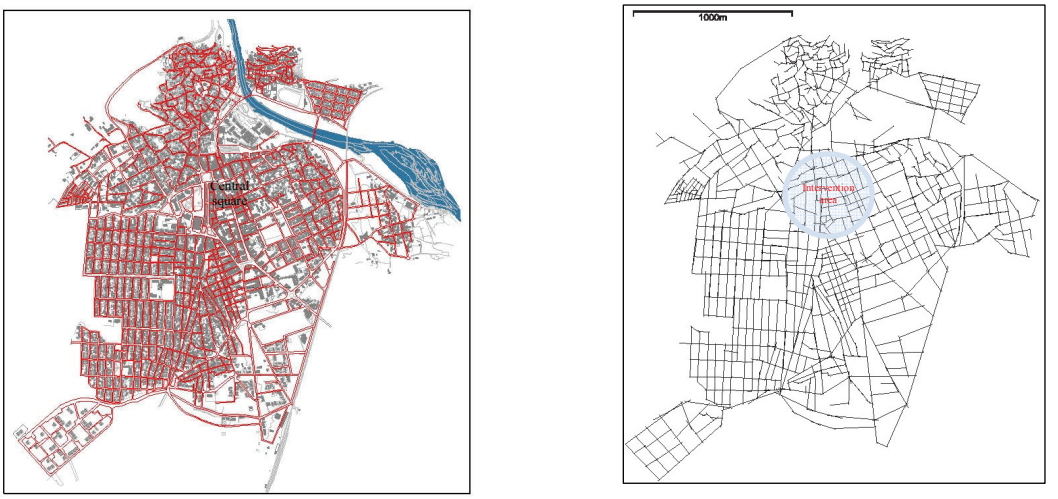

Fig. 1 (a) Map of Xanthi; (b) Axial map of Xanthi

For 40 years, starting from 1870 onwards, Xanthi had been in its most intense phase of development in its history, and it emerged to a commercial, administrative and military centre of the wider area. The financial development of the city mainly relied on the elaboration and trading of tobacco produced in its rural hinterland and was accompanied with high demographic increase. In the end of the 19th century, the city had 10,000 inhabitants and remarkable residential growth, as new neighbourhoods were created outside of the old settlement.

A major part of the city during this period formed its main attributes: the administration and commercial centre in the area around today's central square, the new commercial zone across the principal road axes around the square, the social facilities in the traditional core and the tobacco warehouses in the edge of the city, very close to the road and railway transport axes. At the same time, the old and new bourgeoisie and working-class neighborhoods were defined and divided according to cultural and religious criteria. Simultaneously, the geometric attributes of the urban tissue characterize the form of the city until nowadays: curvilinear alignments in the old residential core, rectangular routes to the new commercial centre and the area of tobacco warehouses, complex alignments with low widths in the working - class areas, more specific routes and independent blocks in bourgeoisie's neighborhoods (Patrikios et al., 2008).

From 1910 onwards, Xanthi was involved in the big wars of the European continent, leading to economic recession. In 1924 refugees from Asia Minor came to the city, increasing its population from 16,000 to 30,000 inhabitants. The refugees' neighborhoods, built using rectangular grid, with elongated blocks of equal size, extended the city mainly to the south-west.

In 1939 the first Zoning and Building Plan was created. The plan suggested new alignments with widening and redirection of certain streets. Nevertheless, it was proved to be practically inapplicable in most cases; in particular, in the old residential cores. After World War II and for 30 years, Xanthi went through a period of financial and demographic decline. During the '70s, the construction of major public buildings, the creation and operation of the School of Engineering of the Democritus University of Thrace, as well as strong construction activity, created a new reality in the built environment: the centre of the city started to take its final shape around the central square, the commercial zones were extended to

the principal road axes and numerous functions were transferred outside the urban tissue; in the south-western part of the city, an organized building unit is created.

Although the reconstruction in small sites with high density had a negative impact on the urban environment of the modern city, the regeneration project which secured the maintenance of the historic core (Old Town), a unique example of a preserved historic district in Northern Greece, is a positive part of the development process (Xanthi Prefecture, 1993).

The recent unification and regeneration, by the Municipality of Xanthi, of the scattered public open spaces of the city centre (including the central square) by the partial pedestrianization of certain streets and point traffic arrangements (Figure 1b), creates new circumstances, the consequences of which are not yet obvious to the function of the city as a whole.

The analysis of the evolution of the urban tissue proves that it has important differentiations in its form as well as its density in different parts of the city. In the neighborhoods of the old residential core, the street network consists of a coherent organic tissue that spreads to the built space and forms it. In contrast to that, in the modern city the urban tissue consists of separate blocks of different geometry, which follow its successive extensions. The western neighborhoods have rectangular geometry, whilst the eastern and southern neighborhoods have different normal geometries but with great variety in the sizes of blocks. The neighborhoods are connected with a system of radial axes focusing on the central square, which is the only articulation point between them and the Old Town.

4. Space Syntax application and results

4.1 Data elaboration and axial map production

The computer program DepthMap with the aid of which the axial maps of Xanthi were produced and the space syntax analysis took place, was created in 1998 by Alasdair Turner in UCL, and was given to the Laboratory of Transport Engineering of Democritus University of Thrace (DUTH), in order to be used for educational and research purposes. DepthMap program is an application used to perform visibility analysis of architectural and urban systems. It takes input in the form of a plan of the system, and is able to construct a map of 'visually integrated' locations within it (Turner, 2004). Version 8.15c of the program was used, which includes full opportunities of creation and analysis of axial maps..

The cartographic information used for the analysis was based on the maps of Xanthi of 1984. The digitalisation and the vector data were taken from diploma theses submitted to the Laboratory of Transport Engineering of DUTH. The background was updated, modified and redesigned using CAD software. The production of axial maps by DepthMap required control and limited intervention, especially for the illustration of dead ends and accesses through the open space stairs in the Old Town (Figure 1b).

4.2 Global integration and integration core

In the global integration map of Figure 2a, it is clearly illustrated that the most integrated axes are associated with the allocation of the commercial land use and the streets that gather recreation and entertainment land use. The method reveals with sufficient precision the majority of the main and most congested streets of the city. This is enhanced by the results of several former transport studies (Stefanis et al., 1994, Papadopoulos and Hadjigeorgiou, 2003) and indicates the major positive correlation of the integration of a street with the trip density and the ability to attract key functions in it. One of the

exceptions is a principal exit road of the city, which does not have high integration values, possibly due to its segmentation in five axes because of the changes in gradient of the city planning grid.

The central square is proved to be the syntax, traffic and functional integration core of the city, as the surrounding streets have the highest integration values. Around the square, particular unities of special uses exist, which are characterized by contrasts, such as the block of administration buildings and open spaces in the west, the most dynamic part of the commercial centre in the south, recreation uses and services in the north and the site of the flea market with specialized shops in the west. The low integration values of the spaces in the internal part of the block of administration buildings in comparison with the very high integration values of the surrounding streets justify the devastation during the afternoon when the passage of pedestrians and vehicles is significantly reduced and confirm the incorrect syntactic structure of the area.

The 40% of less integrated spaces (blue color) indicates four compact neighborhoods that are residential areas with specific and completely discrete syntax and urban attributes (Figure 2a). The first two are located in the southern part of the city, away from the centre and are characterized by poor connectivity and incomplete inner urban organization (lack of centre, limited urban services). The rest two are situated in the north, in an area with intense relief and are characterized by dense organic urban tissue. In particular:

The first neighborhood (1 in Figure 2a), in the south-western part of the city is one of the very few examples of organized building activity in Greece, and it was created by government's intervention through expropriation between 1977 and 1982 (Hadjimichalis, 2010). The dense connective tissue of the refugees' neighborhoods is a tangential boundary, but without the existence of an appropriate connection. The sub-units are formed by different types of housing, while there are few social support buildings and a small market. Unstructured and unformatted areas indicate that the initial project was not completed. The program was initially addressed to social groups of relatively high income. Today the area is an isolated suburb. The composition of its residents has been differentiated comparing to the initial estimations. Social exclusion has started to be produced with a clear spatial expression which is enhanced by the considerable distance from the centre of the city and the poor connectivity with the last parts of its comprehensive tissue.

The second neighborhood (2 in Figure 2a), in the south-eastern edge of the city, close to the river, is a working – class neighborhood with residents of low income, which was formed in the end of the 19th century with the establishment of the slaughterhouses and the tanneries. The neighborhood is connected to the city with one road axis away from its core. Despite the fact that it was developed in smooth terrain, it is characterized by complex alignments with low widths, semi-public flat surfaces – yards and dead ends. This organization produces complicated networks and bad circumstances of living, whilst at the same time encourages the creation of ghettoization tendencies.

The third neighborhood (Old Town) (3 in Figure 2a), was created in the remains of the settlement existing before the earthquake of 1829, in the northern mountainous part of the city. It is characterized by dense urban organic tissue with curvilinear alignments that deliberately created a sense of unfamiliar environment to anyone who did not belong to this community, while at the same time they allowed constant monitoring of all roads from adjacent residences. Using syntax terms, this means achieving low integration values and strict control to discourage the passage of foreigners (Kubat, 1998, Yu et al., 2009). Nowadays, the free organization of the built volume creates an environment suitable for residence and a quality of living that in modern cities is usually met in suburban developments of high income (Giannopoulou, 2008). The area is adjacent to the most integrated space of the city, the central square. In the beginning of the axes which penetrate the area as extensions of the only axis that connects it with the city centre, recreation land use is gathered.

The fourth neighborhood (4 in Figure 2a), was created in the 18th century, in the north - eastern bank of the river, opposite from the Old Town. It is characterized by dense urban organic tissue and relief with intense gradients. In contrast with the Old Town, it has not been subject to any protection status and as a result, unregulated building activity takes place within the traditional tissue that is still maintained.

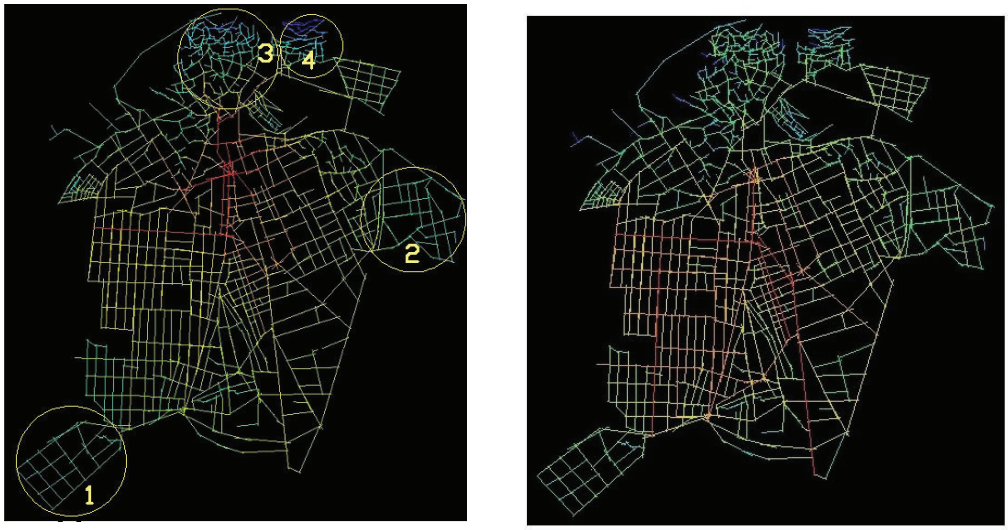

Fig. 2 (a) Global integration map; (b) Local integration map (radius 3)

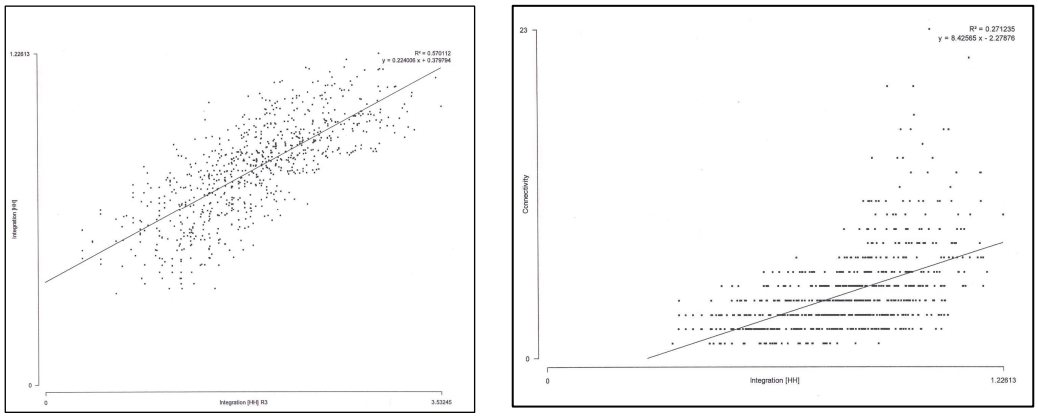

Fig. 3 (a) Scatter plot of the synergy and; (b) intelligibility of the urban tissue

4.3 Local integration, synergy and intelligibility of the tissue

The axial map of local integration (radius 3) for the whole city indicates that the most integrated axes according to the global integration analysis do not always concur with the locally most integrated axes. The central square is not the most integrated part of the city anymore. A major role to this has the big

differentiations of the urban tissue by area as well as the existence of axes with large connectivity and poor integration. The axes that have high local integration values attract commercial uses of local level (Figure 2b).

The system's synergy is shown by the correlation coefficient R^2 of the relationship of global and local integration, which has value of 0.57, and by the corresponding regression equation: y = 0.224006x + 0.379794. As shown in Figure 3a, the group of points has a parallel dispersion around the straight regression line. In contrast to that, the intelligibility of the urban tissue, which is measured by the coefficient R^2 of the correlation between the global integration and the connectivity is not as high (R^2=0.271). The regression line has the following equation: y = 8.42565x + 2.279 (Figure 3b). An intelligible urban tissue can be realized by considering the structure of the global system based on the structure of the local area (Long et al., 2007). In the city of Xanthi, the way the space is formed locally is not ideal for the configuration of a network that can be reached directly and does not help in understanding the aggregate space configuration of its urban tissue (Gatsoulias, 2009).

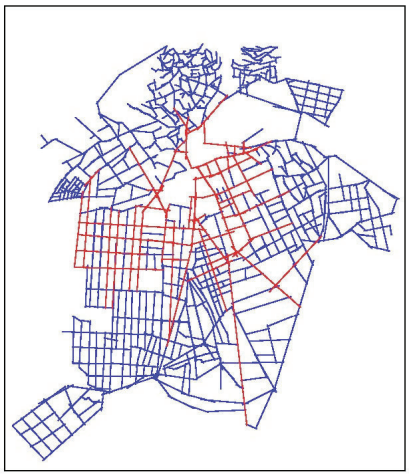

Fig. 4. Axial map of Xanthi – Integration core after the intervention

4.4 Changes in global integration after the recent urban intervention

The recent intervention (2009–2011) of the centre of Xanthi includes the formation and connection of the central square with the open spaces of its western side by the pedestrianization of the streets of highest integration values. It is a regeneration project of large scale, which in addition could create a series of functional problems added to the already existing and enlarged by the lack of a transport study.

In the new axial map (Figure 4), a major decrease of the global integration values is observed, as well as a relocation that influences its highest values zone. As a result, the much integrated centre of the city is moved to the east side of the central square. The range of change, in combination with the small number of axes that have been removed (only 2.31%), shows the importance of the pedestrianized streets for the whole city. Moreover, the most integrated streets in the north – south direction remain integrated, whilst certain streets are upgraded. These streets however, do not have the appropriate geometric attributes to undertake the transfer of traffic. It thus revealed that the complementary use of an analysis of the urban

tissue's configuration of the intervention area with the use of space syntax methodology, could contribute in avoiding such failures and help in achieving the regeneration project's objectives.

5. Conclusions

The syntax analysis of Xanthi, confirmed the location and extent of the commercial and administrative centre of the city. The core of the city was shown with sufficiently large precision and the most important and congested parts of the street network were revealed. Moreover, the commercial streets and the entertainment streets were found and the low intelligibility of the urban tissue of the city was confirmed. The areas that have low integration values coincided with neighborhoods that have attributes of either low accessibility, low trip flow, particular form of the urban tissue, social exclusion, or combination of the aforementioned attributes. Furthermore, the argument that the syntax properties of the urban public space have an impact on the fulfillment of the objectives of regeneration studies was verified significantly.

Although space syntax has been widely used by urban planners, the integration of its modeling capabilities and potentials within other methods of urban and transport analysis could be pursued more often, in order to have computational and substantial completeness of the individual scientific sectors.

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